SOME CONTRIBUTIONS TO THE STUDY OF THE MUSCULAR SENSE.[1]

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THE nearer we approach the subject of sensation, whether it be from the physiological or psychological side, the more complex does it appear. Our knowledge of the cortical representation of sensation, leaving out of view the special senses, is exceedingly vague and uncertain. The analogy which exists between the special senses and general sensibility would lead us to look to the cortex of the occipital or temporo-sphenoidal lobes for the sensory centre, while psychological and we may add physiological reasoning would rather impel us toward the more modern view of a close relationship existing between motor and sensory centres. The more one studies the minute histology of the *cortex cerebri*, the stronger becomes the impression that the systematic arrangement of the cellular elements has something more than a mere histological significance.

Unfortunately experiments upon the lower animals give us very untrustworthy results and aid us very little in the solution of this *quæstio vexata*. Limited cortical lesions in the human subject are comparatively rare, but the results of operations on the cortex for Jacksonian epilepsy would rather give countenance to the modern notion that the motor and sensory centres lie in the same region. The course taken by sensory impulses through the cord is in like manner uncertain. We know that the sensory nerves enter the cord by the posterior bundle, and thence their course is uncertain and various, passing for some distance in the posterior columns, then

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[1] Read at the meeting of the American Neurological Association, New York, June 22, 23 and 24, 1892.

into the gray matter, until they at length converge to the crura and capsules. Our third segment, dividing roughly in this way for the sake of convenience, presents likewise a somewhat unascertained distribution. We understand clearly enough the cutaneous distribution of the sensory nerves, but as yet we are by no means sure of the mode of distribution of sensory nerves to such structures as muscles, tendons, and joints, though Chauveau's recent work makes the existence of sensory nerve endings in muscle highly probable.

The above statement represents in a very general way the sum of our knowledge as to the anatomical relations of sensation, using the term in its physiological significance, and indicates the difficulties that may be expected in the study of the muscular sense, since the latter is afferent in its nature and hence must travel, in part at least, the same paths as do the general sensory impulses.

When we consider the sense of touch we find it divisible into tactile sensations proper, painful sensations, temperature sensations, muscular sensations, and perhaps certain others; and confining our attention to muscular sensations we find that they are compound and may be reasonable subdivided into several groups. First, the pressure sense, which is itself twofold, namely, the perception of pressure, as when weights are laid upon the hand and the discrimination between different weights by balancing them in the hand. The first of these processes is passive in nature and lacks the precision of the second, which is far more active. In the former case the weights must differ by something like one-third before they can be distinguished from each other, while in the latter we can discriminate between weights differing by one-seventeenth.

Second, the sense of coarse movements of the limbs, an active phenomenon, carrying with it somewhat of the sense of resistance.

Third, the sense of effort which certainly owes its existence in part to afferent impulses, though it is perhaps equally certain that it is in part dependent upon central cell activity.

Fourth, that sense by which we are enabled to locate the parts of our body. Gowers call this the rest-posture sense; but as this term is somewhat cumbrous, we will call it simply the posture sense, bearing in mind its purely passive nature. This last subdivision of the muscular sense, or, as we have called it, the posture sense, is the one upon which the remarks made in this paper will most directly bear. It differs in its nature from the first three divisions of the muscular sense according to our arrangement, more widely than they differ from each other, having little or none of the active element which enters largely into the composition of each of the first three varieties, and it also is far more independent of general tactile sensibility than they. A very slight consideration of the phenomena which characterize the posture sense is sufficient to convince us of its importance. By it we are made aware of the position of the various parts of our body, and are enabled to locate them with more or less accuracy without the aid of the other senses. Of course in making tests of the posture sense it is necessary to exclude the other senses, especially sight, since we habitually employ the sense of sight to aid the posture sense. The tests for the recognition of the presence or absence of the posture sense are rather crude. The subject is blindfolded and told to touch certain parts of the body, as the nose, first with one forefinger and then with the other; is required to put the two forefingers together; to place one hand on the other, after varied passive movements have been made with one arm by the operator; is made to put the heel of one foot upon the toe of the other, and is required to imitate as exactly as possible, with one limb, the position of the corresponding limb, which has been arranged by the operator. These experiments may be made reasonably exact, and may be greatly varied as the ingenuity of the operator suggests. One is struck at the outset by the fact that normal individuals vary greatly in the acuity of posture-sense perceptions. It would be impossible in the present state of our knowledge of the subject to fix upon a normal standard. We are obliged to fall back upon our experience and try the cases by an empirical standard that each operator sets up.

Upon second thought, we should expect this variation in any sensory phenomena. Many of the experimentors upon the pressure sense formulate the most exact laws of the ratios of perceptible differences in weights, but the later experiments of Galton and others show that no such exact laws exist, and that the same diversity in pressure-sense perceptions in different individuals obtains as in the case of other sensory phenomena.

When we come to consider the nature of the posture sense, we see that the information that we derive from it must travel in afferent paths, and not as some observers have thought, be partly dependent upon central cell activity. It is not possible to conceive of the posture sense being composed of anything but afferent impulses. We are able to appreciate perfectly the infinite variety in position which our limbs may be made to assume passively, so that the sense of effort cannot enter in as a factor. The knowledge that we gain by the posture sense must necessarily precede the voluntary movements of our limbs. Clinical facts afford ample proof of the afferent nature of the posture sense, for we find it diminished or lost when the lower segments, the nerve or cord, are injured or diseased, the centre in the brain remaining intact. The afferent impulses composing the posture sense differ greatly from most other afferent impulses with which we are familiar in that there is no appreciable reflex time required. We must be kept constantly informed of the exact position of our limbs in order to make the necessary muscular output. If we were ignorant of the exact position of our hand we could not tell how much energy would be required to raise it to the head. We are familiar with the great waste of energy by the tabetic, due to loss of posture sense. He raises his feet higher than necessary, he brings his hand too forcibly upon some object, or he may not expend enough energy at the first effort, and a second is required. Unless his eyes are constantly fixed upon his limbs he is not aware of the position of his arms or legs, and consequently misjudges the amount of force needful for the production of specific movements. In the normal individual, then, this knowledge of the positions of the limbs, of the parts of the body generally, economizes the output of energy, and we can explain its constant nature only by supposing a continuous passage of these impulses from the periphery to the centre. If we were obliged to wait to get a special stimulus from a limb in order to ascertain its exact position before performing any voluntary act, our movements would become too slow to be useful. It is very difficult in the present state of our knowledge to assign any definite function to the centre which acts as the recipient of these afferent impulses. It probably serves to bring these afferent impulses into close relationship with the motor centres. We can probably improve the posture sense by practice, and in children it only gradually acquires precision. A ready explanation of these facts is that the path of the afferent impulses to the motor centres becomes more and more familiar through the agency of the cells which represent the posture sense in the cortex.

Another fact which might be brought forward in proof of a certain activity in the cortical centre of the posture sense is the curious set of sensations experienced by persons who have lost a limb. These individuals, as is well known, very often experience a sense of the presence of the lost member, and this it would seem is sometimes entirely independent of any irritation of the nerve endings in the stump. I recall the case of a man who had his arm amputated near the shoulder, and at first he referred his muscular-sense impressions to his hand, later to his elbow, and finally to the stump, when his posture sense had become properly readjusted. The cells in the cortex have become so habituated to receiving the continuous stimulus from the limb and referring it to or interpreting it as coming from the terminal nerve fibres, that there would seem to be left behind a certain posture memory after the limb has been removed.

It would be interesting to note whether in the case of children who have lost limbs and in whom the cortical cells have not had time to store away impressions to the same extent as the corresponding centres in the adult, the same things obtains. As opposed to this seeming instance of posture-sense memory might be mentioned the sensation of absence of a limb which one sometimes experiences when awaking at night after having lain upon the arm. This sensation is most certainly due to the fact that the customary incoming impulses have been cut off by the temporary pressure paralysis

The analogy between posture sense and muscle tonus seems very close. It is necessary that the muscles be kept slightly stimulated ready for use, with the slack taken in, otherwise when we attempted any voluntary movement time would be lost in getting the muscle taut. So in like manner it is necessary that we be kept informed, so to speak, of the exact position of our limbs that no time be lost in finding them.

The conception, then, that I have of the posture sense, is that it is a distinct, well-defined sense, composed of impulses in the main subconscious, originating in the muscles, joints, tendons and skin, and passing continuously to a centre in the cortex cerebri, which centre is in close relationship with the cortical motor centres.

We come now to the consideration of the clinical facts which bear upon the subject of the posture sense. As has been noted, experiments upon the lower animals offer little or no assistance, for although we can artificially produce in them inco-ordination of muscular movements, it is impossible to say how much this inco-ordination owes to loss of posture sense. We are obliged, then, to fall back upon clinical observations of cases in which there has been noted loss or impairment of posture sense. Unfortunately the posture sense is rarely tested by the general practitioner, and it would appear that it is not always included in the routine examinations in the dispensaries for nervous diseases. Nevertheless there are enough carefully recorded cases to warrant certain conclusions being drawn.

One of the most essential facts to be established, and one which has occasioned a good deal of dispute, is whether, from clinical data, we are warranted in speaking of the posture sense as a distinct variety of sensation. Furthermore, if this be granted, can we separate it from the other members of its class, as the pressure sense, for example.

That the posture sense is entirely distinct from general tactile sensibility there can, I think, be no reasonable doubt, though denied by so distinguished an observer as Dr. Ferrier as late as 1887. References could be given to a large number of cases to prove the truth of this assertion. Bastian has collected a number of typical cases. Erb states that posture sense is independent of general tactile sensibility. Gowers, in his last edition, says "the sense of posture may be lost when cutaneous sensibility is normal, and conversely, the skin may have lost most of its sensitiveness when this knowledge is perfect." I have repeatedly observed in cases of multiple neuritis loss of posture sense at a stage when general sensibility had returned, or in cases showing very little loss of skin sensibility, and on the other hand, preservation of posture sense with very great loss of tactile sensibility. The explanation of this apparently contradictory statement, that in the same disease we find such different symptoms must be looked for either on physiological or anatomical grounds. We often see in cases of pressure paralysis loss of motor power with little or no sensory involvement. In the same way, then, either the fibres of the nerve which conveys posture-sense impressions have escaped injury, or the nature of the injury or disease is such that it interferes more with the conduction of some impulses than of others. A still more conclusive proof of the dissociation of posture sense and tactile sensibility is afforded by the following case recently under my care:

W. L., aged thirty-six, laborer. Family history good. Patient has had syphilis, and examination of his heart shows marked mitral and aortic disease. No very distinct history of rheumatism. On the morning of the attack he felt perfectly well, and while sitting in a chair, after breakfast, was attacked with vertigo and dizziness, and everything became black before his eyes. He fell on the floor, and, from his statement, had only a partial loss of consciousness. He then got up and went to his room and got in bed, and in about an hour he noticed loss of power in his right leg, and shortly afterward in the arm of the same side. Says he was able to talk after the attack, but his friends could not understand him. From close questioning, it was doubtful whether there was any aphasia; certainly there was none a few weeks after the attack. This is interesting in view of the fact that he was distinctly left-handed and conforms to the rule. On examination, a week or more after the attack, there was noted complete right hemiplegia, with marked right facial paralysis. No aphasia. No disturbance of general tactile sensibility. Almost absolute loss of posture sense. I moved the paralyzed arm after having placed my hand over the patient's eyes, and asked him to touch the hand with the sound hand, and after groping about for some time he said he was unable to find it. Similar tests with the legs gave the same result, namely, no loss of general sensibility, with practically absolute loss of posture sense. Temperature sense on the paralyzed side was practically unimpaired, though I may say that the tests for this latter were hurriedly made by my assistant. Temperature sense and tactile sensibility normal on the unparalyzed side. Several months after these observations were made there developed on the paralyzed side a very marked hyperæsthesia, while the posture sense remained absent. Autopsy, made about one year after patient was first seen, showed the internal capsule of the left side softened and broken down. One of the lenticulo-optic arteries was entirely closed. The softening of the capsule extended well into the posterior third of the posterior limb. A number of cases of hemiplegia have since been examined and two cases found in which there was moderately well-marked loss of posture sense;

in one of these cases there was slight loss of general sensibility, in the other it was normal.

Beaunis shows in a very interesting experiment, which, however, seems not to have been repeated, a simple way of dissociating general sensibility and posture sense. A singer was requested to sing a difficult piece of music, and then the larynx was rendered entirely insensitive by cocaine, and the song was repeated with practically the same exactness, thus showing that the muscular and cartilaginous structures of the larynx were capable of making the necessary nice adjustments independently of general sensibility.

We would expect to find a more intimate relationship existing between the various subdivisions of the muscular sense, as they are set forth in the beginning of this paper, than exists between the muscular sense and general tactile sensibility. Whether we can distinctly separate the pressure sense from posture sense, and these two from the sense of resistance and sense of effort is not clear. Among those who have held that several at least of these were distinct and separable parts of the muscular sense, may be mentioned Duchenne. A discussion of this question, however, would extend unnecessarily the limits of this paper.

We may, then, consider it definitely proven that the muscular sense, or at least one part of it, the posture sense, is composed of afferent impulses, which are entirely independent of general sensibility. The next step that suggests itself is the starting-point of these afferent impulses. Clearly, as several observers have noted, the muscles alone—that is, sensations coming from them—cannot give us the information we require as to the position of our limbs. How, for example, could we be made aware of the position of the forearm produced by contraction of the biceps if the impressions came solely from this muscle? We might obtain in this way some general information as to the position of our limbs by means of the memory of the muscular contraction and the result produced, a stored up experience, but it is impossible to conceive that we can in this way be kept informed of the exact position of our limbs. That the muscular element is a very important factor is proven by the fact that the muscular sense of the ocular muscles informs us of the degree of convergence of the visual axes, and consequently is a most necessary element in our appreciation of the size and distance of objects. Undoubtedly the tendons, the joints, and their coverings, and perhaps the bones, all aid in producing the posture sense, or rather from them proceed nerve fibres conveying posture sense impressions.

The course of these impressions is almost certainly through the posterior columns of the cord. The loss or impairment of posture sense is an almost constant symptom in sclerosis of the posterior columns. If it were admissible to draw conclusions regarding the muscular sense from the symptomatology and pathological anatomy of tabes, it would seem that posture-sense impressions run a continuous course in the posterior columns. At all events we find in tabes loss of muscular sense, with often little or no involvement of skin sensibility, and only the posterior columns involved.

It seems to me probable that the fibres conveying the posture-sense impressions pass into the restiform body, thence to the cerebellum and on to the great brain. In three cases of tumor of the cerebellum with autopsies, I have observed loss of posture sense without impairment of general sensibility. In one of these cases the loss of posture sense was practically absolute, and the tumor was found to involve the middle lobe and superior peduncles, pressing also on the corpora quadrigemina. In the other two cases the loss of posture sense, while not nearly so marked as in the case related, was yet decided.

The case of hemiplegia, quoted above, would seem to indicate that the course of the posture-sense fibres is through the anterior portion of the posterior third of the posterior limb of the internal capsule, occupying a position intermediate between the motor and sensory fibres.

In the case alluded to the anterior part of the posterior third was markedly softened, and presented a characteristic worm-eaten appearance, and, as the later history of the case showed, there was enough involvement of the sensory fibres to produce hyperæsthesia on the opposite side of the body, while motion on the opposite side of the body was destroyed, as was also the posture sense.

It remains finally to consider the probable centre for posture-sense impressions, and here speculation is most rife.

Following Ferrier and his school, we should place this centre in the hippocampal lobe. This, however, would be assigning to it a closer relationship to general tactile sensibility than the facts of the case would seem to warrant. If there is one thing certain about the posture sense it is that it exists independently of general tactile sensibility. A far more reasonable supposition, it seems to me, is to consider this centre to be in the closest possible relationship with the motor centres. We have seen how very important this knowledge of the exact position of our limbs must be in view of muscular action. Hence I should be inclined to place the centre for the posture sense either in the convolutions contiguous to the parietal convolutions, or what seems still more reasonable, in one of the several distinct layers of cells which go to make up the cortex of the motor area. Some slight confirmation of this view is obtained from the operations performed by Horsley and others upon the cortex for Jacksonian epilepsy. As a result of these operations there was more or less loss of posture sense in the part whose motor centre was excised. Much more clinical and pathological evidence is needed upon this point, however, before any decision can be arrived at.

The conclusions which may be drawn from the foregoing remarks may be summed up as follows:

1st. The posture sense is composed of afferent impulses derived from muscles, tendons, articulations, and their coverings and bones.

2d. It is independent of and separable from general tactile sensibility, and possibly can be distinguished from the other members of its class, as the pressure sense, for example.

3d. The course of these impulses through the cord is almost certainly by means of the posterior columns.

4th. They probably pass into the *corpus restiforme* and cerebellum.

5th. In all probability they pass through the anterior portion of the posterior third of the posterior limb of the internal capsule, occupying an intermediate position between the motor and sensory fibres in this region.

6th. Without positive data on either side it would seem most probable that the centre for the posture sense is located in one of the cell layers of the motor cortex.

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SOMNAL.

O. M. Meyers, M. D. (Med. Record, March 12, 1892) from a clinical and experimental study of the physiological and therapeutic action of somnal, draws the following conclusions ; Locally it is non-irritant, exerting a rather stimulating effect on the gastric mucous membrane. Applied directly to the frog's heart it destroys its electro-excitability. Therapeutic doses do not weaken the heart. Toxic doses depress that viscus : (*a*) by direct action on the muscle ; (*b*) by stimulation of the cardio-inhibitory centres. After therapeutic doses there may be slight primary rise in arterial tension, which soon returns to normal, or may fall below. Toxic doses rapidly diminish pulse rate and pressure. Ordinary doses cause the respiration to become slow and full. Toxic amounts induce rapid, shallow, and irregular respiration ; the result of depression of the respiratory centre at base of brain. As in therapeutic doses sleep is induced without perceptibly affecting any other portion of the economy, it is fair to conclude that somnal acts directly and primarily upon the cerebrum. A. F.